Asynchronous Contact Tracing

Version v1.1, 14 December 2020

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Executive summary

This document examines the use of IoT technology in contact tracing and introduces the concept of *Asynchronous Contact Tracing* (ACT). ACT identifies contacts with IoT connected objects that have been contaminated by the SARS-CoV-2 virus and works in synergy with solutions designed for manual and digital contact tracing to identify and alert people who may have been infected by the virus.

This shifts the paradigm *from* synchronously tracing the contacts of the people infected by Covid-19 *to* asynchronously tracing of contacts of materials (such as infected surfaces, waste-water, air-conditioning filters, etc.) that are hosting the SARS-CoV-2 virus.

This enables people who have come into contact asynchronously with those particular materials to be alerted of a potential Covid-19 contagion, and, at the same time, it signals that one or more persons have been in contact with the material which is now spreading the SARS-CoV-2 virus.

This process could be particularly effective, considering that the SARS-CoV-2 virus can survive for a significant time on certain materials [15]. The level of contamination depends on the nature of the surface the concentration of the virus, the ambient temperature, the season of the year, the level of humidity, and exposure to sun light. The period of contamination can span from a few hours to several days.

The ACT process uses existing, ready-to-market IoT-based technology and well-established wireless network techniques. The process is not dependent on achieving a certain number of tests, or of people adopting it, in order for the results to be useful. Moreover, it does not require the transmission of any personal information by the user, thus respecting both EU GDPR and public sensibility to personal privacy.

This process was inspired by Occam's Razor [5] or the *Law of Parsimony* (Latin: *Lex Parsimoniae*), that states that entities and theories useful to solve a problem should not be multiplied unless necessary. On the contrary, simpler entities and theories are preferable to more complex ones because they are easier to test and more likely to be true.

Asynchronous Contact Tracing

Asynchronous Contact Tracing (ACT) is a process (network protocol + appropriate IoT infrastructure based on SmartM2M/oneM2M + mobile and web applications) conceived for regular 'peace time' use, as opposed to (Synchronous) Contact Tracing protocols [6,7,8,9] which tend to be employed when society is put on an urgent, war footing in reaction to an acute problem[1] [11].

The ACT process is not only applicable to the current pandemic wave. The parameters can be adapted to any other virus in a future pandemic.

ACT will be socially and economically acceptable to people who should view it as a *National Service* (*i.e.* offered by, the Public Health Authorities) and not be viewed as an obligatory *requirement*.

ACT will promote individual testing only in the unfortunate event of the user receiving official notifications that he/she may be potentially at risk. It can be applied to all the contexts where people share the same physical space, such as a supermarket, schools, restaurants, hotels, gyms, offices, working plants, hospitals, hospices, etc. It can also be applied to an object that is encountering people while it is in movement, such as a public transportation network.

ACT tests materials that have been in contact with humans and uses wireless and IoT technologies to notify a particular contamination event to Public Health Authorities that, in turn, will inform users who were potentially close to those infected areas.

The process is intrinsically *asynchronous* because it does not require people to be in the same place and at the same time, and, more importantly, it does not require any information exchange between humans, since the virus has been detected by Group Testing on materials and not on humans.

For many communities, this type of tracing will support an elaborate form of *selective lockdown*, *i.e.* the surgical closure of specific areas following a forecast announcing a new spike of infection. It is without doubt a process that will naturally benefit many social and industrial organizations, cities, tourism, education, commerce, and travel etc.

[1] "*C'est un projet qui répond à une crise historique sans laquelle il n'existerait pas et au-delà de laquelle il n'existera pas : l'épidémie de Covid-19*". [11].

Introduction

Lockdown

The main weapon against Covid-19 currently available is social distancing and it requires full/partial/selective lockdown of cluster areas in the event of a high peak in the spread of the virus. This creates severe damage to an economy and to the personal life of its citizens. While we are all waiting for a vaccine, the other relevant tool in the fight against the virus is testing. Unfortunately, widespread testing of large populations in a very short time remains unpracticable. A single testing would require some 1ML tests per week and about 60 weeks for a nation such as France. This is clearly an unworkable solution to the problems raised by the current pandemic and is common to most countries across the world.

It is also clear that many people are unwilling to be Covid-19 tested for social reasons, such as job restriction, economic consequences, violation of private life, or even fear of quarantine. It is now well understood that without widespread testing of the population, the only weapon against Covid-19 is lockdown and subsequent severe economic and social disruption.

Contact Tracing

Contact Tracing (CT) has been actively used in Europe since the 16th century to contain epidemic disease. The principles remain the same today whether carried out by phone, mail or personal contact. The aim is to identify the origin of the infection and to where, or to whom, it has been transferred. If receipt of this information is followed immediately by isolation, treatment and aggressive decontamination, it can lead to containment and the gradual elimination of the disease itself.

This year has seen an explosive demand for information about Covid-19. It rapidly focused on the possible use of new technology, and particularly on the capabilities of the mobile phone to automate the process of 'track and trace', producing more accurate and timely information flows - to the advantage of public health, governments and the patient and their personal contacts. The potential of 5G and AI seemed to beckon to a future where silent, rapid transmission of data would protect us all from an unseen virus that observes no political or social boundaries.

There was an immediate counter reaction - this degree of protection might also be intrusive. It threatened the security of our private lives, our right to move freely and our right to confidentiality, particularly in the medical field. There have been many public statements asserting that current practice of CT observes Human Rights as expressed by the EU, but the resulting focus on the individual subject of CT has led to much confusion as to the purpose and direction of the resulting data collection.

Who Needs to Know? And What do they Need to Know?

These are questions that initially were considered to have obvious answers. Design of ICT systems for CT would follow the traditional, manual methodology but should make it faster, more accurate, more useful. Solutions were found to protect the individuals' personal rights and freedoms, but little attention was paid to the 'back-end' - the ultimate destination of the data and the use to which it would be put.

Put simply, it has always been true that security and transparency share a trade-off. One threatens the other. If the potential patient, the user of the 'track and trace' enabled phone is to be fully protected then the program must not store their name or contact details in any way that could lead to their identification.

This debate has distracted attention from an important issue. Track and trace exercises in the past have been used principally to support government and public health initiatives not just to inform the individual as to their potential risk. Our modern focus on the rights of the individual threatens the management of track and trace data, which could seriously minimize its usefulness to central authorities which we hold responsible for containing the infection.

Testing for the SARS-CoV-2 virus

Testing is essential to the fight against the SARS-CoV-2 virus and it must be accurate. At the present moment, there are different products based on two methodologies, namely virologic tests (*e.g.* RT-PCR) and antibodies tests. Unfortunately the accuracy of the tests is not absolute, and this lead to test repetitions and especially to interpret inconsistent results, *e.g.* VIRAL=POSITIVE and ANTIBODY=NEGATIVE.

There is a further problem caused by the number of commercial products available with varying standards of accuracy as well as the high cost of some testing kits. *e.g.* see [12].

Today, as we write, there is a plethora of test solutions (ex: TUL, TDR, TROD, PCR ...). This "abundance" is neither helpful nor economically sustainable. Some of the tests require access to specific processing equipment which may be expensive or not generally available in local hospitals or laboratories. The last frontier is the Rapid Antibody Test (< 30 minutes) intended for the use as an aid in identifying individuals with an adaptive immune response to SARS-CoV-2, indicating prior infection. This rapid lateral flow test is intended for the professional use in laboratory and near patient-testing environment and qualitatively detects IgM and IgG specific to SARS-CoV-2 in serum, plasma, and whole blood.

Dorfman's Group Testing Process

During the 2nd World War Professor Dorfman invented a group testing method to screen for syphilis amongst American soldiers. The testing process we aim to use is inspired by the principle of Dorfman's Group Testing described in his seminal paper, "*The detection of defective members of large population"* [1]. The rationale of Group Testing is simple. A sample of blood is taken from, say, five people. These samples are mixed together and one test for the virus is made on the combined fluids. If this test result is negative then all five individual samples are considered to be negative, thus saving four test kits. If the result is positive then the original five samples must be tested individually.

The testing methodology applied in the ACT process is a subset of the Dorfman Group Testing, namely, we are interested only in the presence or absence of the SARS-CoV-2 virus in order to make the ACT process work; the reason for this is trivial because we cannot identify the 'infectors' of waste-water, or air-filtering or other materials (the waste-water or the air-filtering act like an hash-function, *i.e.* it would be computationally impossible to come back to the infectors. Note that infector here is used to denote either humans or things hosting the virus.

Use of this sub-kind of group testing (sometimes called pooling testing), in combination with modern digital IoT technology, can provide a new and effective *'forecast'* for the introduction of '*selective lockdown'*; this means that whenever we test an infected location, the ACT technique will communicate to the population a precise geographical area which can be defined immediately as safe or un-safe.

Asynchronous Contact Tracing

Today, *Synchronous Contact Tracing* (SCT) [6,7,8,9] protocols are all being designed to exploit the following digital information; namely, physical and spatial proximity, whilst preserving personal anonymity, in order to track the chain of transmission of the virus.

The challenge of *Asynchronous Contact Tracing* (ACT) is to remove the *time* and *space* limitation and to trace only *surfaces* that have been contaminated by the virus, rather than just the *persons* potentially infected. The SARS-CoV-2 virus is known to stay viable for a variable time on a hard surface, depending from the nature of the surface, the virus concentration, the temperature, the humidity conditions, the exposition to sun light. This time can vary from few hours to several days, some examples are 2-3 hours on paper, 4 hour on copper, 3-4 days on plastic and steel, 7 days on face masks, and even more in specific climate conditions [2,3,4,15].

Typical hard surfaces at risk include items such as a plastic drink bottle, a can of beer, a milk carton, a water tap or electric towel in a public toilet, a park bench, a metro train's doors, seats and buttons, ATM machines etc. In reality this includes everything around us.

ACT is a process that exploits the following digital information:

- The possibility of testing *material* (waste-water / air-conditioning filters / hard surfaces) using standard, reliable, testing techniques and producing results in reasonable time [13]. By results here we mean the percentage of SARS-CoV-2 virus on that material without adding information about who infected it. The accent is therefore on the infected object and not on the person. This is an interesting application of Dorfman's Group Testing techniques. Note that we are not interested to go further in the investigation of who (as a person) really is infected: here the focus is on the fact that a given material or location is infected and, as such, it need to be closed to the public and people whose visited those locations or touched those material should be informed and suggested to go fast for a RT-PCR test.

- The result of testing materials are first interpreted by the National Public Health authorities into a precise forecast, which is geo-localized and then widely communicated to the population using WiFi[2] and well-established Web techniques. Access to the forecast may be achieved by a mobile application or by querying a Web-accessible data-base.

Note that the user does not need to communicate his position nor his identity or pseudonyms but has just to listen to the forecast or query the Web-accessible data-base.

This is why we consider ACT to be an intrinsically '*asynchronous'*.

To resume, the main objectives of ACT are:

- to trace the IoT that "hosts" the SARS-CoV-2 virus instead of the people that got infected by the SARS-CoV-2 virus;
- to inform National (and Inter-National) Health Authorities so that they can establish common Policies and local, selective, *surgical* lockdown in a timely and effective manner, and avoid the severe economic, social and psychological disadvantages of *full generic* lockdown;
- to forecast for the public information on the clinical status of areas which may be infected and new clusters where the virus is spreading.

Two Simple Scenarios for Asynchronous Contact Tracing

Scenario I

Let us imagine that Alice is infected without knowing and goes shopping at the supermarket at 10:15am; she touches some items or sneezes or coughs on them or just breathes close to some items. She then leaves the supermarket. The corridors that Alice walked, its caddy and the goods that Alice touched are surely infected by SARS-CoV-2 virus.

Now let us imagine that Bob, who is not infected at all, visit the same supermarket corridors, (unfortunately take the same caddy) and touches those same items at 11:00am, unfortunately and involuntarily infecting him by SARS-CoV-2 virus.

The following considerations are now in play:

- Synchronous Contact Tracing Protocols [6,7,8,9] cannot allow the exchange between Alice and Bob of pseudonyms, because their respective mobile phones and contact tracing apps *were not present and active at the same place* (let's say less than 1 meter) *and at the same time* (let's say for at least 15 minutes).
- If Alice is later tested Covid-19 positive, then there are no means by which Bob will ever be informed and yet this is a likely to be a common means of transmission of the virus.
- It is not necessary to test Alice to inform Bob that he was potentially infected: it would suffice to test the items that Alice touched and the corridors that Alice walked, because Bob did probably the same.
- It is not even necessary for Alice to exist as a physical person, because the virus could transfer on to a surface as a result of coming into contact with other contaminated surfaces, such as articles being sent from an infected region.
- If Alice were infected in the same conditions as Bob but *two days before* in another supermarket, and if Alice had been informed about the potential risk of infection, then she probably would have done a unitary test (RT-PCR) and, if positive, she would not then touch the items in the supermarket because she would have stayed at home, and probably not infecting Bob.

Scenario II

Alice buys chocolate from the supermarket in Paris. The outer packaging is contaminated and she may receive a dose of the virus. That same day, Bob buys the same chocolate in Lyon, from the same supermarket chain as does Marie in Antibes and Mario in Turin the day after. The supermarket chain has adopted the ACT technology. It follows that all four supermarket corridors selling chocolate are

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[2] It is a work in progress.

measured positive with the SARS-CoV-2 virus during the cleaning that takes place every two hours in those supermarkets. The consequences of those four measures are as follows;

- Isolate the fours corridor, stop sales of chocolate items in the four supermarkets;
- Verify and warn factory, country of origin and logistics.

In conclusion, ACT can be a practical *virus-tracing* tool, following the *supply chain* related to chocolate in that supermarket chain.

ACT in action

ACT performs tests on all materials. If the test is positive, then the following actions could be performed:

- Immediate publishing of the test result on a Public Web-accessible Database with consequent immediate publishing of the isolation/closure of the potentially infected location on a Public Web-accessible Database.

The tasks performed by the smart application associated with ACT are to:

- listen and record all the Peripheral Service and memorize their identifier;
- match all of the identifiers sent by the National Control Service, each of one associated with a precise forecast, with the one he/she has recorded, and, in case of non-empty intersection, notify immediately a potential contamination to the owner of the smartphone. At that point he/she may decide (or not) to go to a laboratory for an individual test;
- ask its National Control Service to be informed about the forecast by other foreign Inter-National Control Services.

The tasks performed by the PC Application associated to ACT are to:

- access the forecast produced by the National Control Service;
- with a simple GUI, also to access precise forecast relative to the local area, denoted via suitable coordinates eg. latitude, longitude, and radius.

Functional Units

Asynchronous Contact Tracing process can be explained as follows by introducing the following SmartM2M/oneM2M functional units as described in the following Figure describing the ACT method architecture [14].

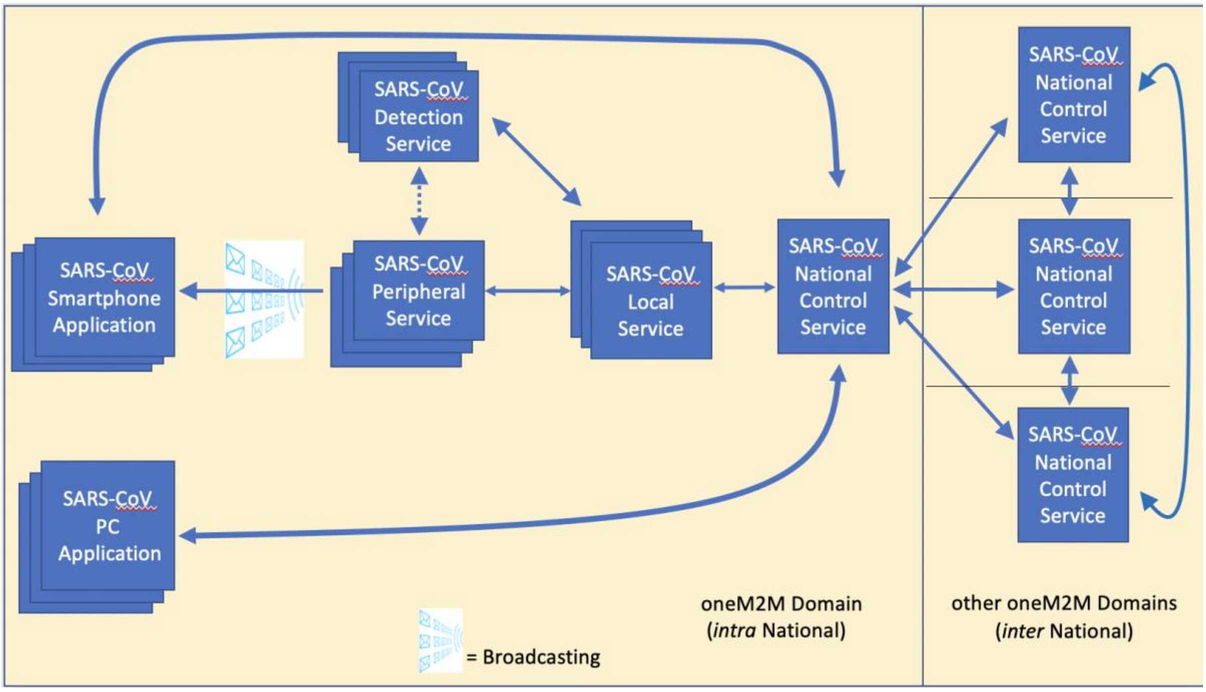

Figure 1: ACT Method Architecture

- A *Peripheral Service*, placed in a specific location, such as a supermarket corridor, a public toilet, a metro station, a fitness room etc. has the capability to transmit, using WiFi technology, the following information such as its unique identifier (also known as the MAC identifier BSSID).
- The *Smartphone Application*, called *IoTAntiCovid* , is the main digital tool available to the user to monitor the level of contamination. It collects the identifier from the one or many Peripheral Services and periodically compares it the identifier-related forecast published by the National Control Services, with an associated time and forecast, and about potential contaminated areas. It also receives the local forecast when approaching one or many Peripheral Services and will periodically warn the user according to the Public Health Policies received by means of the one or many National Control Service. The IoTAntiCovid application also offers the opportunity to request and receive forecast about other Peripheral Services (not necessary the one he/she was close) information always without communicating its user's location. The periodicity of the request will be configurable by the IoTAntiCovid application.
- The *PC Application*, called *IoTAntiCovid -PC*, is an user connected device (tablet, personal computer, smart TV, etc.) that communicate with the National Control Services to query and receive back information about the status of the situation in specific geographical areas. By *delegation* it can also query other Inter-National Control Services. It basically supports the user about the discover of its own risk according to the past visited areas and/or to plan his movement and behaviours in advance. The purpose of IoTAntiCovid -PC is similar to the Smartphone Application, namely be informed about the forecast of the virus, but its UX/UI is rather different.
- The *Detection Service* informs the one or many *Local Services* about the detection of the contamination in one of the proximity areas associated to one or many Peripheral Service. The chemical process and the kind of test used to check the material for contamination (*e.g.* air-filter, waste-water filter, dirty cleaning tools and water, etc.) are not *strictu sensu* pertinent to ACT Technical Specification. Each Detection Service can be associated with one or many Peripheral Services and it shall communicate with the one or many *Local Services* the detection of a contamination. It will exchange its monitoring and configuration information with one or many Local Services, including means to exchange the information necessary to the management of the specific detection tool.
- The *Local Service* receives the information from one or many Detection Services belonging to it and propagates this information to the *National Control Service*. It receives the necessary indications, in order to behave according to the National Authorities policies for the one or many Peripheral Services configuration (*e.g.* for the broadcast frequency of the identifier or for the emission of the forecast information). It will also transmit to the National Control Service the identifiers of the one or many Peripheral Services involved in a positive detection, together with their location and the approximate range of the detection. Finally it will exchange monitoring and configuration information with the National Control Service.
- The *National Control Service* will receive the information from the one or many Local Services related to contamination and will provide to it information according to the Public Health Authorities policies on the one or many Peripheral Services configuration (*e.g.* for the broadcast frequency of the identifier or for the emission of the forecast information). The National Control Service also represents a point of interaction with the users. It provides, on request, the identifier of the one or several Peripheral Services announcing contamination to the many Smartphone Application IoTAntiCovid and additional information about indications and suggestions according to the Public Health policies (*e.g.* the suggestion of avoiding certain areas or to perform a human test verification if certain conditions of exposure are met, according to the detection of the virus in the areas covered by one or many Peripheral Services). The National Control Service will exchange its monitoring and configuration information with the one or many Local Service and with the many Smartphone Application IoTAntiCovid . It will also coordinate and communicate the information about the areas of detection of the virus with one or many Peripheral Services in other Nations or Regions. Finally, the National Control Service will be in contact with others National Control Services in order to exchanges forecast, common Policies so informing users of different Nations, Regions or Municipalities, etc., when they are traveling from home. This enables ACT to be a genuine, international forecast tool.

Conclusion

To resume the main contribution of ACT is to use a sub-kind of group testing, in combination with modern digital IoT technology, to provide a new and effective *'forecast'* for the introduction of '*selective lockdown'*; this means that whenever we test an infected location, the ACT technique will communicate to the population a precise geographical area which can be defined immediately as safe or un-safe. We are interested only in the presence or absence of the SARS-CoV-2 virus in order to make the ACT process work; the reason for this is trivial because we cannot identify the 'infectors' of waste-water, or air-filtering or other materials. Note that infector here is used to denote either humans or things hosting the virus.

Acknokledgements

The authors acknowledge Dr. Patrick Guillemin (ETSI) for hit technical suggestions and friendly support.

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